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(71) Applicant(s)
Jisoon Ihm
114-406 Olympic Sunsoochon Apartment,
89 Bangee-dong, Songpa-gu, Seoul, Republic of Korea

(72) Inventor(s)
Jisoon Ihm

(74) Agent and/or Address for Service
Reddie & Grose
16 Theobalds Road, LONDON, WC1X 8PL,
United Kingdom

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(56) Documents Cited
GB 2353631 A **WO 98/11588 A1**
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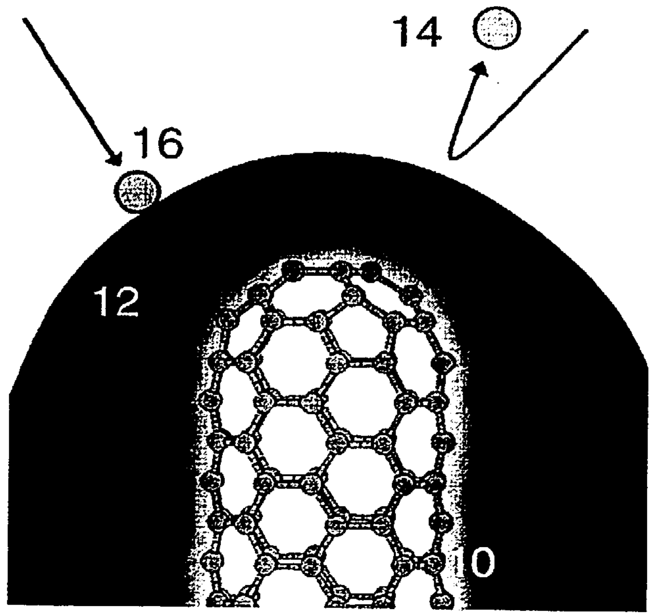
(54) Abstract Title
Carbon nanotube field emitter

(57) An electron field emitter is formed by coating a carbon nanotube 10 with a very thin layer of insulating or semiconductor material 12 with a high degree of hardness. The emitter can be used in various field emission devices such as a nanotube based field emission display (see fig 4) and a microwave amplifying device. The layer of deposited material protects the carbon nanotube 10 from external particles 14 16, particularly positive ions, which can for example drop out of a phosphor coating on the screen of a display device and collide with the nanotube emitter. The layer prevents deformation or destruction of the emitter structure while allowing electrons to be emitted easily under a lower applied voltage, thereby improving uniformity and stability of emission. The material can by deposited using an argon sputtering technique or electron beam evaporation, and formed of compounds of boron, nitrogen and carbon, including diamond.



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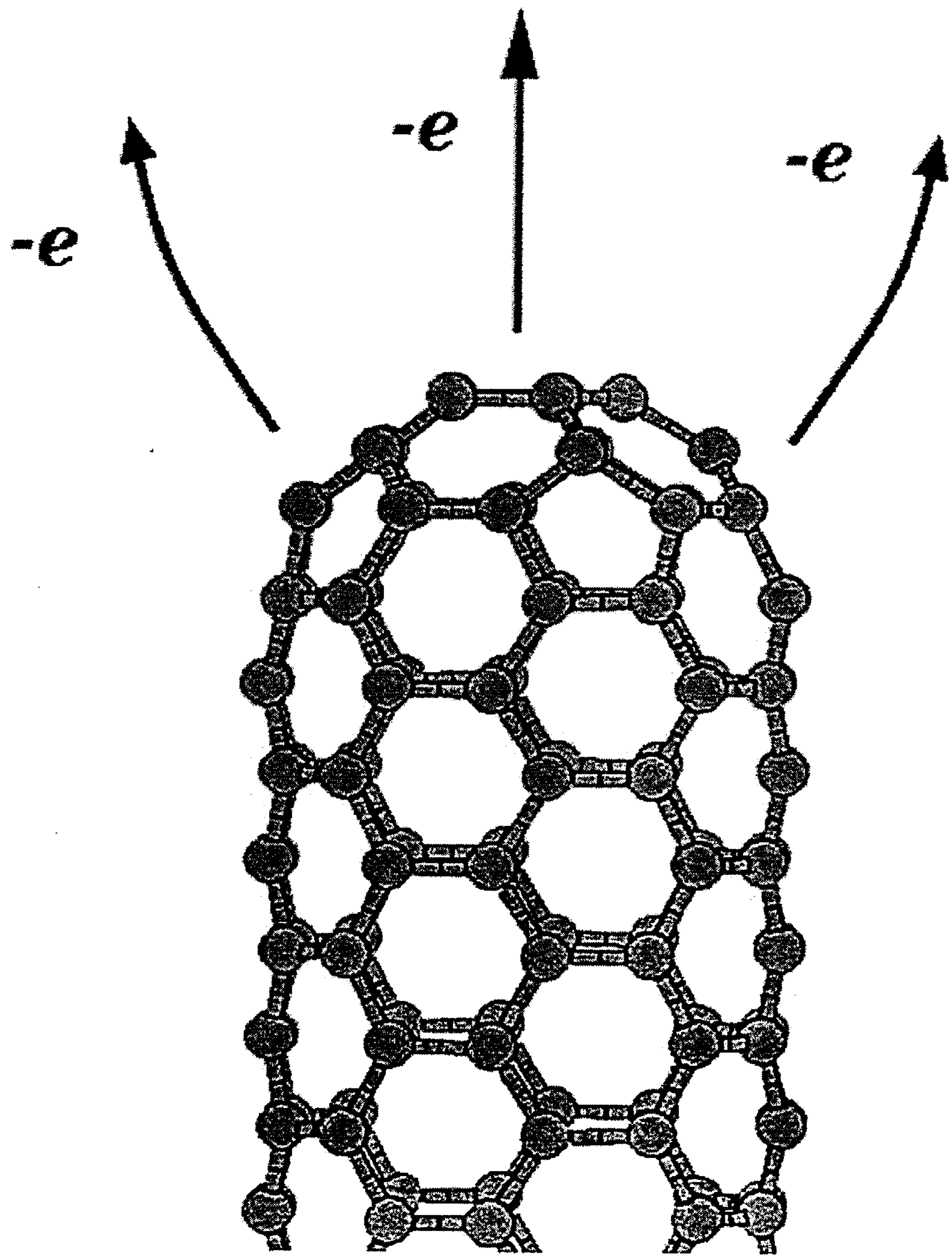

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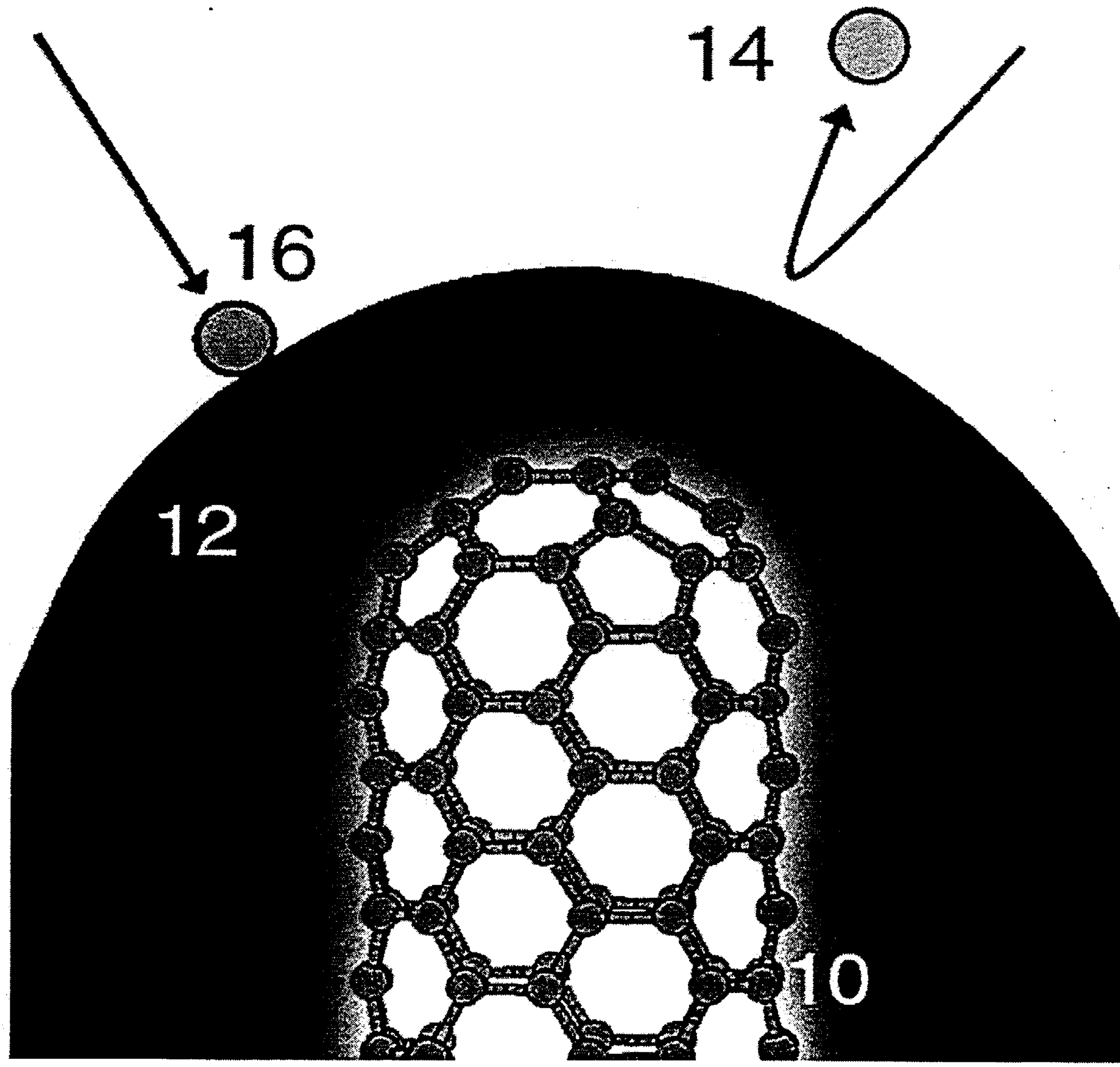

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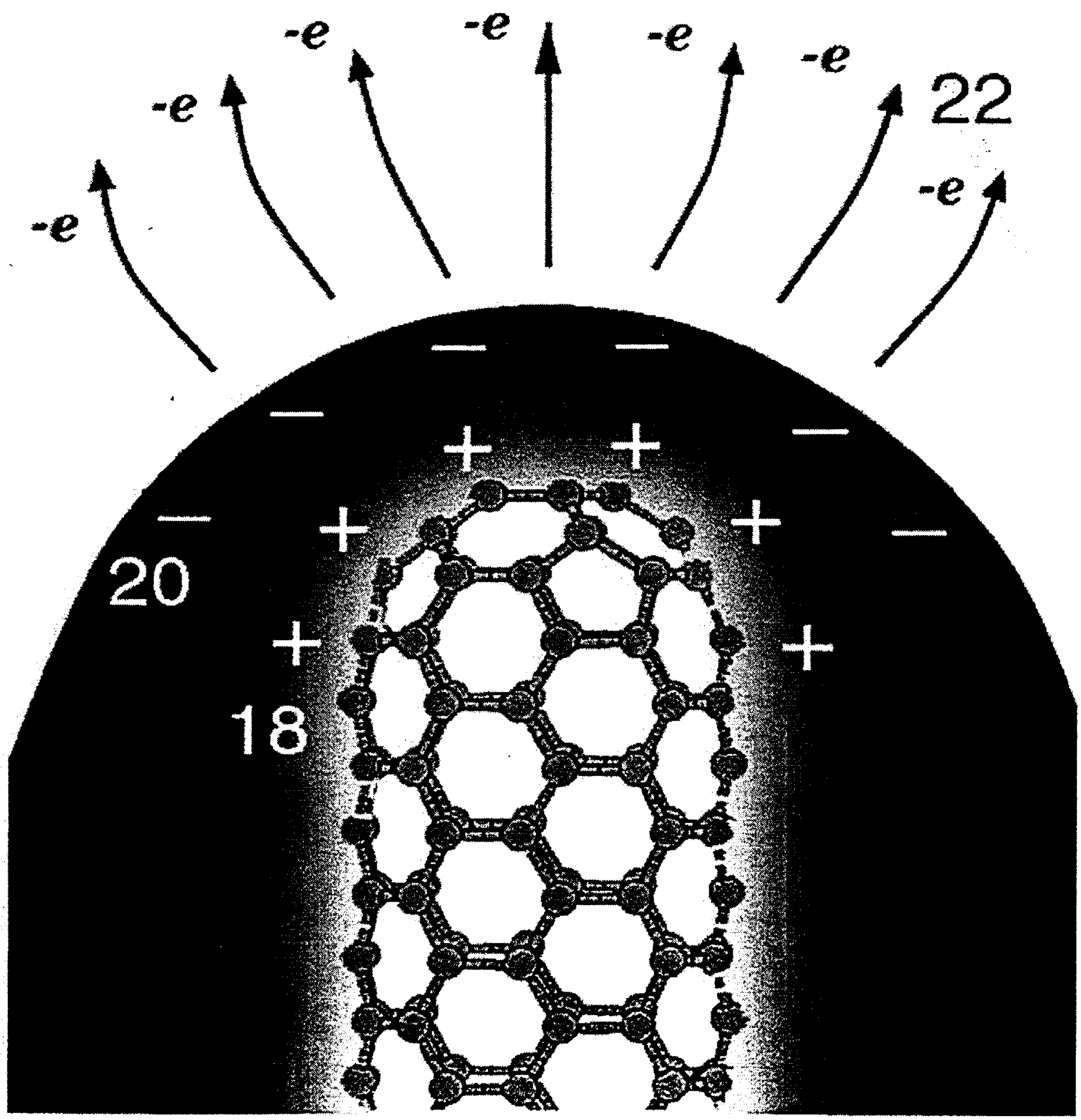

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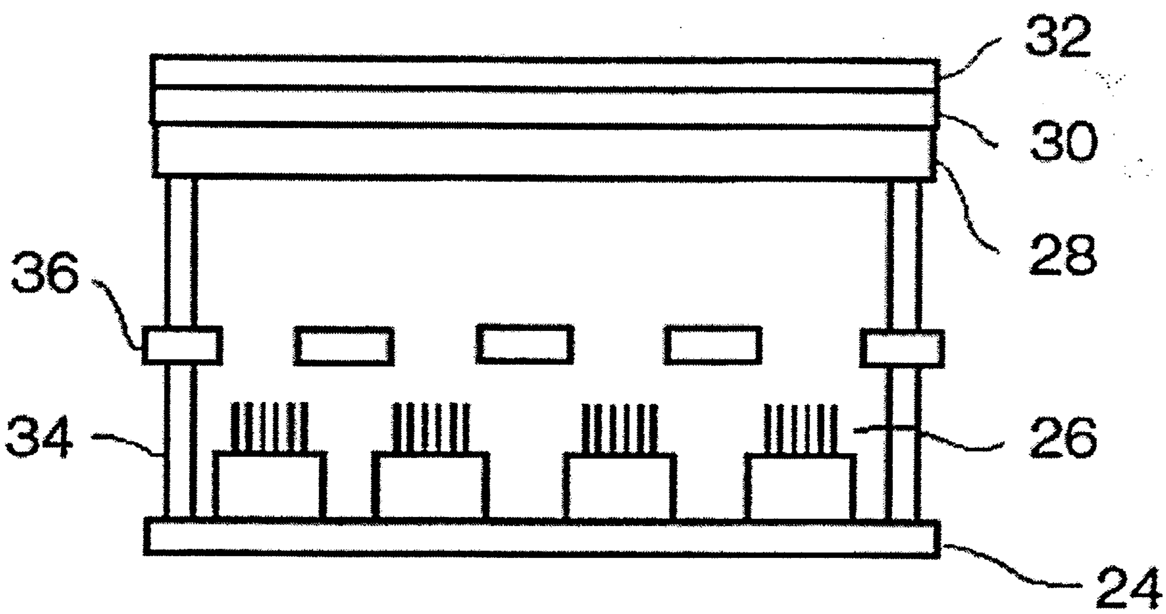

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TITLE OF THE INVENTION

A STRUCTURE OF AN EMITTER FOR FIELD EMISSION DISPLAY

FIELD OF THE INVENTION

The present invention relates to a field emitter for various kinds of devices including a nanotube-based display and a microwave amplifying device, and more particularly to a field emitter using a carbon nanotube as an emitter material in a display device which uses a field emitter. Herein, "display device" is intended to cover all of other display devices using a field emitter.

BACKGROUND OF THE INVENTION

A field emission display (FED) device of which concept was already introduced in 1968 has been continuously researched and developed as a new generation of the display device following a CRT(Cathode Ray Tube), TFT-LCD and a large screen PDP.

In such field emission display, one of the most important elements is a field emitter which is equivalent to an electron gun of a CRT and, as its material, a metal (mainly, molybdenum), a semiconductor, a diamond and the like have been considered. Since a suggestion concerning the use of a carbon nanotube as the emitter material in about 1995, there have been performed research and development associated with the use of the carbon nanotube.

Using the carbon nanotube as an emitter has advantages that the carbon nanotube emitter is much thinner than a conventionally used emitter, there is created a high electric current under an application of a low voltage, there is increased a redundancy by virtue of a large number of tips existed therein, and bonding characteristics of carbon guarantees a structural stability higher than a metal emitter.

Approaches for manufacturing the carbon nanotube suggested up to the

present include the followings:

First, to vertically grow carbon nanotubes on a substrate by passing hydrocarbons on the substrate covered with a catalyzer such as nickel and the like using a chemical vaporation deposition (CVD) method;

Second, to plentifully create carbon nanotubes using an arc discharge or a laser ablation method that is usually used in prior arts, mix them with other metal adhesive agent and then arrange the mixed material on the substrate; and

Third, to form a set of parallel carbon nanotubes by applying bias to aluminum which is immersed in an acid solution and letting the aluminum oxide film to be eroded continuously so as to make regularly perforated, fine holes thereon (using so called an anodic alumina method) and then passing hydrocarbons through the holes.

Fig. 1 shows a schematic representation of a conventional (not coated) carbon nanotube wherein an arrow indicates a direction of electrons (-e) emitted when a voltage is applied to the carbon nanotube used as a cathode. In practice, there exist a large number of nanotube tips, but herein, only one representative nanotube is shown.

In spite of the development efforts of such nanotubes, there exists a big problem that in use, its structure may be deformed or destructed, resulting in instability or interruption of its operation.

The main reason why an emitter in operation gets out of order is that when an accelerated electron collides with a phosphor thereby to emit a light, a positive ion dropped out of the phosphor is invertedly accelerated and collides with the emitter. For that reason, uniformity, stability and durability of a display screen do not reach a level required for a commercial use.

SUMMARY OF THE INVENTION

Accordingly, in view of the problems, it is an object of the invention to provide a cabon nanotube-based field emission emitter capable of greatly improving the performance of a field emission display by coating a tip of the carbon nanotube with a semiconductor or insulating layer having a high degree of hardness at a thin thickness within several nanometer(nm) so as to protect the tip for emitting electrons from a collision with the external particles and thereby to establish the durability and stability of the carbon nanotube as well as to reduce a required applied voltage thereto.

In accordance with one embodiment of the present invention, a field emitter comprises a semiconductor or insulating layer deposited thereon by evaporating the semiconductor or insulating layer on the carbon nanotube using an electron beam evaporation method .

In accordance with other embodiment of the present invention, a field emission emitter comprises a semiconductor or insulating layer deposited on the carbon nanotube by sputtering argon on a semiconductor or insulator knockout the constituent atoms and inject them onto the carbon nanotubes.

In addition, it is possible to deposit a semiconductor or insulating layer on a carbon nanotube by using all methods which are used for making a very thin molecular layer such as a laser ablation method, a conventional CVD method and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic representation of a conventional carbon nanotube wherein an arrow indicates the direction of electron emission.

Fig. 2 shows a schematic structure of a field emitter in accordance with the present invention, wherein a carbon nanotube is protected from a collision

with external atoms or particles by a thin semiconductor or insulating layer coated thereon.

Fig. 3 shows a schematic representation of amplification of field emission by a structure of a field emitter in accordance with the present invention.

Fig. 4 shows a schematic representation of the use of a field emission tip mounted on a field emission display in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 2 is a side view of a field emitter in accordance with a preferred embodiment of the present invention. In practice, there exist a large number of carbon nanotube tips, but only one representative nanotube tip is shown herein. Also, although a simple nanotube, so called (5,5) nanotube is shown as an example herein, but the same result is obtained in case of the nanotube having a different winding shape and size as well as a single-wall or multi-wall structure.

Using such coating method as explained above, the carbon nanotube (10) is coated with a semiconductor or insulating layer (12) of high hardness, which is n-type doped and has a good durability against a collision with the external atoms or particles (usually, positive ions), at a thickness within several nanometer(nm). For the coating purpose, kinds of B, C, N compounds including BN, GaN, Si_3N_4, TiC, B_4C, etc., kinds of oxides including TiO_2,Al_2O_3, MgO, etc, and parts of ferroelectrics including $SrTiO_3$, etc. can be used. it is possible to use diamond-like carbon(DLC) or diamond particles without performing an n-type doping. The external particles, for example, atoms or positive ions(14) dropped from the phosphor may collide with the semiconductor or insulating layer (12) and be bounced back therefrom or

adsorbed on the surface thereof.

Meanwhile, if a bias voltage is applied to the carbon nanotube from the outside, a strong electric field occurs on the tip of the carbon nanotube. In this case, due to a potential distribution within the coated material, the potential energy becomes lower in proportion to a distance from the tip of the carbon nanotube and the potential barrier is reduced. Accordingly, as shown in Fig. 3, a strong electron emission can be induced at a low bias voltage. Since the semiconductor or insulating layer has dielectric properties, if a voltage is applied to the layer, positive charges(18) are induced around the carbon nanotube and negative charges(20) are induced on the surface of the semiconductor or insulating layer. Therefore, as indicated by the arrow (22), a large number of electrons are emitted out of the semiconductor or insulating layer, compared with the case of Fig. 1 where the carbon nanotube was not coated. Under n-type doping, electron conduction occurs newly within the semiconductor or insulating layer, making the flow of electrons smooth. Also, by making the semiconductor or insulating layer as thin as possible, electron scattering can be greatly reduced.

Fig. 4 shows a schematic representation of the use of a field emission tip mounted on a field emission display in accordance with the present invention. Although the inventive field emission tip is constructed on an existing field emission display, the field emission tip is characterized in that it is formed by an array of carbon nanotube coated thinly with a semiconductor or insulating layer, as illustrated in Fig. 2.

As shown in Fig. 4, a pixel is composed of an anode plate(30) coated with a phosphor (28), field emission tips formed of carbon nanotubes coated in accordance with the present invention, and spacers (34) having a small vacuum gap maintained therebetween. Also, a field emitter array (FEA) panel

constructed by two-dimensionally arranged pixels comprises a cold cathode plate (26) installed on a glass substrate (24). A metal grid (36) which is located between the cold cathode (26) and the anode plate (30) controls the amount of electrons emitted from the cold cathode plate (26) to the anode plate (30). Horizontal and vertical electrodes are arranged on the cold cathode (26), and the FEA is matrix-addressed through the electrodes. Therefore, during the time when a voltage is applied to the metal grid (36), electrons are emitted and then accelerated by an anode voltage applied to the anode plate (30). Then, the electrons pass through the vacuum gap and strike the phosphor coated on the anode plate, thereby causing a light emission. Reference 32 indicates a conductive glass (indium tin oxide : ITO) covering the anode plate.

The remarkable feature of the present invention is to protect the carbon nanotube from collision with the external particles (mainly, molecules or atoms having positive charge). As shown schematically in Fig. 2, since the carbon nanotube is protected by the semiconductor or insulating material which has a good durability against collision due to its strong bonding characteristics, the coated carbon nanotube causes electron emission to occur steadily and continuously, thereby greatly improving the brightness of a display device and its durability.

As discussed above, by coating a tip of the carbon nanotube with a thin semiconductor or insulating layer with n-type doping and a high degree of hardness, the carbon nanotube can be protected from collision with external particles and an electron emission is greatly increased under a low applied voltage. Accordingly, the field emitter formed of the carbon nanotube in accordance with the present invention can be greatly improved in its durability and stability as well as can be driven by a low applied voltage. Therefore,

the field emitter invented here can be effectively applied in making various kinds of devices of a field emission-type display.

Various modification and alterations of the present invention will become apparent to those skilled in the art without departing from the scope and spirit of this invention, and it should be understood that this invention is not to be unduly limited to illustrative embodiments set forth herein.

Claims

1. A method for forming a field emitter comprising the steps of evaporating a semiconductor or insulating material on a carbon nanotube using an electron beam evaporation method, and depositing the semiconductor or insulating layer thereon.

2. A method according to claim 1, wherein the emitter is formed by depositing a semiconductor or insulating layer on said carbon nanotube using an argon sputtering method.

3. A method according to claim 1 or 2, wherein said semiconductor or insulating material coated on the carbon nanotube is n-type doped so as to enhance the conduction of electrons, in case that the material can be n-type doped.

4. A method according to claim 1 or 2, wherein the semiconductor or insulating material is one of the materials including kinds of B, C, N compounds including a BN, diamond-like carbon, and diamond, kinds of oxide insulating material, parts of ferroelectrics, which have a high degree of hardness and strong durability against a collision of atoms or molecules.

5. A field emitter formed using the method of any of claims 1 to 4.

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INVESTOR IN PEOPLE

Application No: GB 0122262.9 **Examiner:** Geoff Holmes
Claims searched: All **Date of search:** 14 March 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H1D (DATX, DPD)

Int Cl (Ed.7): H01J 1/304, 3/02, 9/02

Other: Online: WPI, EPODOC, JAPIO, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X P	GB 2353631 A	[PRINTABLE FIELD EMITTERS] particularly see page 8 line 12	1
X P	WO 01/61719 A1	[FULLERENE] particularly page 9 lines 8-22 and example 1	1, 2, 4 & 5
X	WO 98/11588 A1	[ZETTL et al] particularly page 4 line 30 to page 5 line , and figure 6	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.